

- 1 1. A neuromorphic circuit for a Hebbian synapse including an alpha function circuit, an  
2 NMDA ion channel circuit, and a non-NMDA ion channel circuit having a conductance level,  
3 comprising:  
4 a control circuit for coupling with the non-NMDA ion channel circuit to control the  
5 conductance level of the non-NMDA ion channel circuit in response to a voltage level on a  
6 synapse calcium capacitor that is indicative of a calcium concentration in the synapse circuit.
- 1 2. The circuit according to claim 1, wherein the control circuit includes a counter.
- 1 3. The circuit according to claim 1, wherein the control circuit includes a counter for  
2 loading the conductance level of the synapse and decrementing, incrementing, or  
3 leaving the same, the conductance level.
- 1 4. The circuit according to claim 1, wherein the control circuit includes a threshold  
2 circuit coupled to the synapse calcium concentration capacitor for providing  
3 potentiation charge and depression charge signals.
- 1 5. The circuit according to claim 4, wherein a state of the potentiation charge signal  
2 corresponds to a voltage on the synapse calcium concentration capacitor in  
3 comparison to a first voltage threshold.
- 1 6. The circuit according to claim 5, wherein a state of the depression charge signal  
2 corresponds to the voltage on the synapse calcium concentration capacitor in  
3 comparison to a second voltage threshold.
- 1 7. The circuit according to claim 4, wherein the control circuit further includes a  
2 potentiation discharging and charging circuit coupled to the threshold circuit for  
3 charging a potentiation capacitor when the voltage on the synapse calcium  
4 concentration capacitor exceeds the first threshold.

- 1 8. The circuit according to claim 7, wherein the control circuit further includes a  
2 depression discharging and charging circuit coupled to the threshold circuit for  
3 charging a depression capacitor when the voltage on the synapse calcium  
4 concentration capacitor exceeds the second threshold.
- 1 9. The circuit according to claim 8, wherein the control circuit further includes a  
2 potentiation detector circuit for providing a potentiation signal to the counter having a  
3 state that corresponds to a voltage level on the potentiation capacitor and a depression  
4 detector circuit for providing a depression signal to the counter having a state that  
5 corresponds to a voltage level on the depression capacitor.
- 1 10. The circuit according to claim 9, wherein the states of the potentiation signal and the  
2 depression signal can modify the conductance level of the synapse.
- 1 11. The circuit according to 9, wherein the control circuit further includes an up/down  
2 counter circuit that loads the conductance level of the synapse, and wherein the states  
3 of the potentiation signal and the depression signal determine whether the counter  
4 increments, decrements, or leaves the same, the synapse conductance level.
- 1 12. The circuit according to claim 11, wherein the counter is an up/down counter having a  
2 counter value of at least six bits corresponding to the conductance level of the  
3 synapse.
- 1 13. The circuit according to claim 9, wherein the potentiation capacitor has a smaller  
2 capacitance than the depression capacitor.
- 1 14. A neuromorphic Hebbian synapse circuit including an NMDA ion channel circuit and  
2 a non-NMDA ion channel circuit, comprising:  
3 a control circuit for adjusting the synapse conductance level in response to a voltage  
4 level on a synapse concentration capacitor, the control circuit including

5                   a threshold circuit providing a potentiation charge signal having a state  
 6 corresponding to a comparison of a voltage on the calcium concentration capacitor to a first  
 7 voltage threshold that corresponds to long term depression of the synapse, the threshold  
 8 circuit further providing a depression charge signal having a state corresponding to a  
 9 comparison of the voltage on the calcium concentration capacitor and a second voltage  
 10 threshold that corresponds to long term potentiation of the synapse;  
 11                   a potentiation discharging and discharging circuit coupled to the threshold  
 12 circuit for selectively charging a potentiation capacitor based upon the state of the  
 13 potentiation charge signal and for selectively charging a depression capacitor based upon the  
 14 state of the depression charge signal;  
 15                   a potentiation detector circuit coupled to the potentiation discharging and  
 16 charging circuit for providing a potentiation signal having a state determined by a voltage  
 17 level on the potentiation capacitor;  
 18                   a depression detector circuit coupled to the depression discharging and  
 19 charging circuit for providing a depression signal having a state determined by a voltage level  
 20 on the depression capacitor; and  
 21                   a counter for loading the conductance level of the synapse and incrementing,  
 22 decrementing, or leaving the same, the conductance level based upon the states of the  
 23 potentiation signal and the depression signal.

1   15.   The circuit according to claim 14, wherein the counter has a counter value of at least  
 2       six bits.

1   16.   The circuit according to claim 14, wherein the counter is time shared between further  
 2       synapses.

1   17.   The circuit according to claim 14, wherein the potentiation capacitor has a smaller  
 2       capacitance than the depression capacitor.

1   18.   A method for controlling a neuromorphic Hebbian synapse circuit having a synapse  
 2       calcium concentration capacitor that charges in response to stimuli and a synapse conductance

3 level that corresponds to a conduction state of electrical pathways in the synapse circuit, each  
4 of the electrical pathways having a switching element that determines the conduction state of  
5 the electrical pathway, the method comprising:  
6       controlling the conduction state of the switching elements by  
7           providing a potentiation charge signal having a state corresponding to a  
8 comparison of a voltage on the calcium concentration capacitor to a first voltage threshold  
9 that corresponds to long term depression of the synapse;  
10          providing a depression charge signal having a state corresponding to a  
11 comparison of the voltage on the calcium concentration capacitor and a second voltage  
12 threshold that corresponds to long term potentiation of the synapse;  
13          selectively charging a potentiation capacitor based upon the state of the  
14 potentiation charge signal;  
15          selectively charging a depression capacitor based upon the state of the  
16 depression charge signal;  
17          providing a potentiation signal having a state determined by a voltage level on  
18 the potentiation capacitor;  
19          providing a depression signal having a state determined by a voltage level on  
20 the depression capacitor; and  
21          incrementing, decrementing, or leaving the same, the synapse conductance  
22 level based upon the states of the potentiation signal and the depression signal.

1 19. The method according to claim 18, wherein the synapse conductance level is defined  
2 by at least six bits.

1 20. The method according to claim 18, further including selecting a capacitance value for  
2 the depression capacitor that is less than that of the potentiation capacitor.